

HEARTS IN THE LAB, HANDS FOR THE EARTH: AI BIOINFORMATICS IN RURAL EDUCATION (A PHENOMENOLOGY STUDY)

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Abstract

This study explored the integration of technology (AI and bioinformatics) in socio-ecological projects as a means of strengthening character values among high school students who enrolled in biotechnology for young learners. These students came from three different schools in Northern Luzon, Philippines. Conducted within a biotechnology enrichment class for young learners, the project encouraged students to address real-world environmental challenges in the rural communities of Tuguegarao, Gataran, and Antipolog in the Northern Philippines. The learning cycle comprised three phases: students were first introduced to innovative technologies and applications; they then investigated issues affecting local rivers and soils; and finally, leveraging AI and related applications, they designed enzymes with potential use in bioremediation.

Guided by a qualitative phenomenological approach, this research focused on the lived experience of students for their experienced character development, scientific engagement, and rich personal reflections from students. The observation class, students' reflection, and the deep interview were compiled and clustered into a coding system with pointers: basic skills on AI and biotech before joining the program, empathy, critical thinking, collaboration, and a sense of social responsibility.

Beyond technical skills in AI and bioinformatics, the project fostered empathy, critical thinking, collaboration, and a sense of social responsibility. The findings highlight the potential of technology-based socio-ecological projects not only to enhance scientific literacy but also to cultivate character values essential for human dignity and ecological sustainability. This approach demonstrated how integrating AI-driven biotechnology education with local environmental contexts can empower youth to become ethically grounded innovators in addressing global challenges.

Keywords: AI, biotechnology for young learners, future global education, phenomenology research, socio-ecological project

Introduction

The rapid advancement of artificial intelligence (AI) and bioinformatics has opened new opportunities for transforming science education, particularly in the context of secondary-level biotechnology programs. Biotechnology education for young learners has traditionally emphasized laboratory skills, fundamental



biological concepts, and the ethical implications of genetic and environmental interventions. However, the integration of computational technologies, such as AI-driven modelling and bioinformatics tools, provides unique avenues for enhancing not only technical literacy but also the character development of students who are increasingly positioned as future innovators and problem-solvers (Timmis et al., 2017).

In the Philippine context, biotechnology education remains in its formative stage, especially at the high school level, where enrichment classes and specialized programs are limited to select schools. However, local environmental issues such as river pollution, soil degradation, and improper waste management demand innovative and socially responsible solutions. Embedding AI and bioinformatics into socio-ecological projects gives students the opportunity to directly connect scientific inquiry with their lived realities, thereby cultivating empathy, collaboration, and social responsibility alongside critical thinking skills (Prensky, 2010).

Previous studies have highlighted the role of technology-driven learning in shaping student engagement and value. For example, Kim and Reeves (2007) found that project-based learning involving real-world challenges improved collaboration and reflective thinking among school students. Similarly, Timmis et al. (2017) argued that digital tools can support identity formation in learners as they position themselves within scientific communities. These findings suggest that embedding AI and bioinformatics in community-based projects has the potential to strengthen students' scientific identity and moral awareness.

This study is situated within biotechnology enrichment classes for high school students in Northern Luzon, Philippines. It focuses on learners from three schools who engaged in a three-phase project cycle: (1) introduction to AI and bioinformatics tools, (2) investigation of environmental issues in local rivers and soils, and (3) the design of enzymes for potential bioremediation applications. Through a qualitative phenomenological approach, the study aims to explore students' lived experiences in these activities, particularly how their engagement fostered character development, empathy, collaboration, and critical thinking.

The specific objectives of this study are to:

1. Examine how the integration of AI and bioinformatics influenced students' understanding of biotechnology concepts and applications.
2. Explore students' reflections on their personal values and social responsibilities as they worked on socio-ecological projects.
3. Identify the ways in which collaborative learning in biotechnology projects shaped their interpersonal and scientific engagement.

This paper begins with a review of related literature on technology integration, project-based learning, and character education in science. It then presents the methodological framework of the phenomenological study, followed by findings from student reflections and project outputs. The discussion highlights how AI-driven biotechnology education can simultaneously promote scientific literacy and character development, and the conclusion emphasizes its implications for future science pedagogy in the Philippine context and beyond.

Method

Research Context and Participants

The study was conducted within the Biotechnology for Young Learners program facilitated by Kryacademia, an enrichment academy providing specialized science education to high school students in Northern Luzon, Philippines. The Participants included students from three partner schools who voluntarily enrolled in the biotechnology enrichment classes. The class emphasized AI applications, bioinformatics, and their integration in socio-ecological projects addressing real-world challenges in local communities.

Data Sources

The primary sources of data were threefold: (1) classroom observations conducted by the researcher, (2) in-depth discussions with students to align with the phenomenological approach, and (3) students' outputs, including assignment completions and reflective journals. The journals, completed at the conclusion of each project phase—(a) introduction to AI and bioinformatics, (b) community investigation of river and soil issues, and (c) enzyme design for bioremediation—documented the students' personal reflections, experiences, and perceptions of their learning and character development. These were further supported by project artifacts (such as enzyme design proposals), which provided additional evidence of student engagement and understanding.

Research Design

This study employed a qualitative phenomenological approach, which seeks to describe and interpret the lived experiences of participants in order to uncover the essence of the phenomenon under study (Moustakas, 1994). The Interpretative Phenomenological Analysis (IPA) was applied to this study, aimed to explore in detail how participants made sense of their personal and social world. In this case, the phenomenon of interest was the experience of integrating AI and bioinformatics into socio-ecological projects and its perceived influence on student character and scientific engagement. Kahija (2017) mentioned this approach involved a detailed examination of the participants' experiences, attempts to explore personal experience, and was concerned with an individual's personal perception or account of an object or event, as opposed to an attempt to produce an objective statement of the object or event itself.

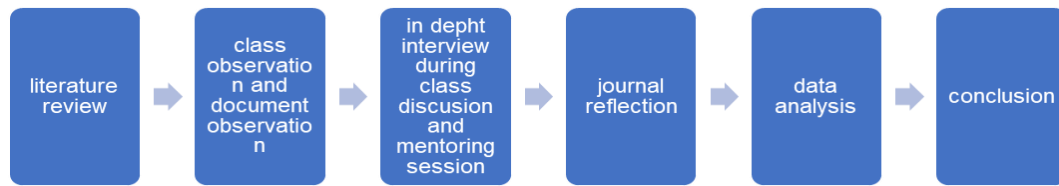


Figure 1. Research Design

Data Collection Procedure

Students were asked to write reflective journals guided by prompts that encouraged them to express their thoughts on scientific engagement, personal growth, collaboration, and social responsibility. These reflections were submitted electronically through a secure platform provided by Kryacademia. Project artifacts were also collected and reviewed to triangulate student perspectives with their tangible outputs.

Data Analysis

Data analysis followed a thematic coding process. First, all reflective journals were transcribed into text files and organized by participant codes (e.g., Student 01, Student 02). The researcher engaged in open coding to identify recurring ideas and experiences, followed by axial coding to cluster these into themes related to character development, empathy, collaboration, and critical thinking (Strauss & Corbin, 1998). Thematic patterns were then validated by cross-referencing with project artifacts and observation notes to ensure credibility and trustworthiness.

Ethical Considerations

All participants were informed of the purpose of the study and provided consent prior to participation. Anonymity was ensured by assigning codes to participants instead of names. Participation was voluntary, and students were informed that their decision whether or not to participate would not affect their academic standing in any way.

Findings and Discussion

Findings on Students' Background in Biotechnology and Bioinformatics

The participants in this study came from three secondary schools located in the province, where access to advanced technology and digital resources is limited. This context is significant, as it shaped both their prior knowledge and their initial engagement with biotechnology and bioinformatics.

Table 1. Students background

Name of School	Province	Number of students	Background
SPUP	Cagayan	8	Tuguegarao City is a rapidly developing provincial capital in Cagayan Valley that serves as a major educational centre
PPIS	Rizal	1	scenic city on the slopes of the Sierra Madre east of Metro Manila — known as a pilgrimage/tourist destination with viewpoints, local handicrafts and a cooler, greener environment compared to Metro Manila
CDNHS	Cagayan	3	Gattaran is largely rural/coastal with notable natural sites (shell middens, caves, springs, falls) and a tropical monsoon climate; schools here are typically in a more rural, community-centered environment
Total		12	

Students' responses revealed that they had minimal background in biotechnology and no practical exposure to bioinformatics before the project. Their understanding of biotechnology was mostly drawn from classroom discussions, often limited to theoretical concepts. For example, while they were familiar with the idea of biotechnology in agriculture or health, they had not encountered its application through computational tools or problem-based projects.

When introduced to bioinformatics and artificial intelligence, many students described the experience as entirely new and technically overwhelming. One participant shared that "observing the proteins was the most challenging part," while another admitted that "everything looked complicated—especially with coding." Such reflections highlight how their rural school settings, with limited access to technology, contributed to their lack of prior experience in computational biology.

Despite these constraints, the provincial students demonstrated adaptability by engaging with tasks that were far beyond their usual academic exposure. The data show that they entered the project from a position of limited access and limited background knowledge, yet were able to build an initial foundation for understanding how biotechnology and bioinformatics intersect.

In summary, the findings confirm that the students' backgrounds were shaped by their context: three provincial schools with restricted access to technology, resulting in minimal prior exposure to bioinformatics. This context makes their subsequent learning experiences and reflections particularly meaningful, as it

underscores the transformative role of introducing advanced scientific concepts to learners in resource-limited educational environments.

Findings on Students' Perception of Including AI and Bioinformatics in Biotechnology

The students' reflections revealed varied but generally positive perceptions of the integration of artificial intelligence (AI) and bioinformatics in biotechnology. Three themes emerged: **recognition of complexity, appreciation of innovation, and relevance to science learning.**

Recognition of complexity and difficulty.

Students acknowledged that integrating AI into biotechnology was not an easy process. They described tasks such as protein modelling, coding, and problem identification as overwhelming at first. One participant reflected that “the most challenging part was observing the proteins. It was hard to understand how they were modelled and how AI could predict their structures.” Another noted that “everything looked complicated—especially with coding,” underscoring the steep learning curve they experienced when encountering AI and bioinformatics tools.

Appreciation of innovation and potential.

Despite the challenges, students recognized the significance of integrating AI and bioinformatics into biotechnology. They expressed appreciation for how technology could deepen understanding of biological systems and open possibilities for problem-solving. As one participant described, “it was exciting to see how technology and biology can work together,” while another reflected that it was “amusing...everything that was displayed as a 3D structure is a part of us humans.” Such statements highlight students' perception that AI does not replace biology but enriches its application.

Relevance to their identity as science learners.

Students also perceived the integration of AI and bioinformatics as transformative for their growth as learners. They emphasized how the experience expanded their understanding of what science could encompass, moving beyond textbooks to computational tools and applied problem-solving. One participant explained that the program “expanded my learning area as a science learner—that there was more to study and explore,” suggesting that students valued the inclusion of AI and bioinformatics as a way to broaden their scientific identity.

In summary, students perceived the inclusion of AI and bioinformatics in biotechnology as both challenging and meaningful. While they struggled with the technical complexity, they also recognized its innovative role in advancing biotechnology and acknowledged its importance in shaping them as science learners.

Findings on Students' Personal Values and Social Responsibilities

The students' reflective journals revealed that engaging in biotechnology and bioinformatics projects extended beyond technical learning; it also fostered growth in personal values and strengthened their sense of self. Three main themes emerged: environmental concern, empathy and responsibility, and the value of collaboration.

Heightened environmental concern

Students consistently connected their scientific activities with the environmental issues they observed in their communities. One participant noted that “*many rivers are either dried up or so polluted that they have a strong smell,*” which led them to recognize that science should address urgent ecological problems. Another emphasized that “*the whole part of actually dedicating a project against plastic and water pollution is already a proof about the responsibility we have as part of the society.*” These reflections show that students internalized environmental responsibility as a core value linked to their scientific work.

Empathy and responsibility toward the community

The reflections also highlighted how students began to see science as a tool to serve people. Observing the state of rivers and soils evoked empathy, with one student expressing, “I felt empathy when I saw how damaged the rivers were, since the community relies on them for water and livelihood.” This sense of empathy translated into responsibility, as another student described joining clean-up drives after conducting their study. Such accounts suggest that students recognized the interconnection between environmental care and community well-being.

The value of collaboration and collective responsibility

Through their group projects, students reflected on the importance of collaboration, not just for completing tasks, but also for cultivating responsibility toward one another and society. One participant emphasized that “collaborating with my teammates was the most meaningful part,” explaining how shared ideas created both memorable experiences and purposeful innovation. Even students who worked independently expressed that balancing different roles in their project pushed them to think critically about responsibility and sustainability.

In summary, students’ engagement in biotechnology and bioinformatics fostered personal values of empathy, environmental concern, and collaboration, while also strengthening their sense of social responsibility. Their reflections show that the project went beyond technical learning, encouraging them to see themselves not only as students of science but as active contributors to society and the environment.

The data in Table 1 summarizes the students’ learning progress throughout the biotechnology and bioinformatics enrichment class. Overall, students demonstrated high levels of understanding across cognitive, affective, and social dimensions of learning. While 85% of students showed an adequate grasp of basic biotechnology concepts, slightly fewer (72%) were able to confidently use bioinformatics tools such as protein modeling and coding applications. Nevertheless, this still reflects a promising outcome given that many students had no prior experience with computational biology.

Students’ reflections revealed a meaningful cognitive shift, as expressed by one participant: “*I realized that even though the topics were complex, I was able to follow and learn from them.*” Such statements indicate self-efficacy and metacognitive awareness, which are critical components of higher-order scientific thinking (Kim & Reeves, 2007).

Tabel 2. Students' Progress

Learning Indicator	Classroom Evidence (Conversation/Presentation/Worksheet)	% of Students Who Achieved
Understanding of basic biotechnology concepts	“I realized that even though the topics were complex, I was able to follow and learn from them.”	85%
Familiarity with bioinformatics tools (e.g., protein modelling, coding)	Students successfully identified proteins using bioinformatics software during group activity.	72%
Application of science to community/environmental issues	“I felt empathy when I saw how damaged the rivers were, since the community relies on them for water.”	78%
Collaboration and group problem-solving	Students brainstormed solutions to water pollution and presented a project against plastic waste.	90%
Development of responsibility as science learners	“This project expanded my learning area as a science learner—that there was more to study and explore.”	82%

Students' Progress in Biotechnology and Bioinformatics Class Based on Background and Classroom Performance

Students in this study came from different provinces and socio-economic backgrounds, bringing with them distinct local wisdom and environmental experiences. In the first session, an ethnoscience approach was used to ground their scientific inquiry in familiar cultural and ecological contexts. Through discussions of local cases, such as the condition of rivers, soil degradation, and the use of herbal plants, students were encouraged to identify community issues and connect them to biotechnology concepts.

Ethnoscience enables learners to see science through the lens of their cultural heritage, fostering meaningful connections between scientific inquiry and lived experiences (Aikenhead & Ogawa, 2007). In this course, the use of NCBI, RBS, Replit, and AI-powered applications provided students with access to advanced tools, while the ethnoscience framework ensured that technological exploration remained socially and environmentally rooted. This aligns with Cajete's (2015) assertion that science learning grounded in community experience nurtures not only knowledge but also ethical awareness and responsibility.

The second and third sessions emphasized design thinking and digital prototyping using AI and bioinformatics tools. Initially, students expressed difficulty navigating coding environments and modeling software. However, as the sessions progressed, they began to enjoy the process, demonstrating increased confidence and curiosity. They developed 2D conceptual designs of enzymes, apps, and prototypes intended to address real community problems such as water pollution and plastic waste. These findings resonate with Holmes et al.'s (2019) argument that AI integration in education enhances students' creative and analytical capacities, especially when tasks are authentic and socially relevant.

A strong affective theme emerged from the students' reflections. Many expressed empathy toward environmental issues: "*I felt empathy when I saw how damaged the rivers were, since the community relies on them for water.*" Through group-based inquiry and collaborative design, they developed a sense of social responsibility and interdependence.

The high rate (90%) of students achieving collaboration indicators underscores the importance of project-based and community-linked science learning. Consistent with Prensky (2010) and Tan and So (2019), the integration of technology-driven projects enhanced both collaboration and values formation, positioning students as active agents of change rather than passive recipients of knowledge.

Notably, the culminating stage—where projects were showcased internationally—served as an empowering experience. Two projects were presented at the *International Children's Conference*, three at the *Global Innovation Field Trip*, and one project won the *Invent Future Global Innovation Challenge*, representing the Philippines at the *Innovation Exchange Singapore*. Students reported increased confidence, pride, and scientific identity, affirming Timmis et al.'s (2017) observation that digital and project-based learning environments can strengthen learners' sense of belonging within the scientific community.

The integration of ethnoscience, AI, and bioinformatics demonstrates a holistic approach that combines technical mastery, cultural grounding, and moral engagement. Students not only learned how to use tools and design biotechnological solutions but also understood *why* these solutions matter to their communities. The development of empathy, collaboration, and scientific responsibility mirrors the broader goal of values-based science education (Timmis et al., 2017; Cajete, 2015).

Such outcomes suggest that blending *local wisdom* with *global technology* can nurture compassionate innovation—a form of learning that equips students with the competence and conscience needed to address real-world challenges in science and society.

Conclusion

The students' perception of including AI and bioinformatics in biotechnology began with an overwhelming understanding of protein modelling, coding, and problem identification, but the students were excited to continue the work and completed the tasks. In the creation process, they were prototyping the project through AI and found it meaningful for society. The reflection shows concern, social responsibility, and empathy toward the community. All the hard work had been showcased in international events such as IKC, IFGIC, IESG, and GYIS. The project went beyond technical learning, encouraging them to bring the best version of themselves to contribute to society.

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